ProtoDUNE PDS Michel Tagging Update

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Introduction

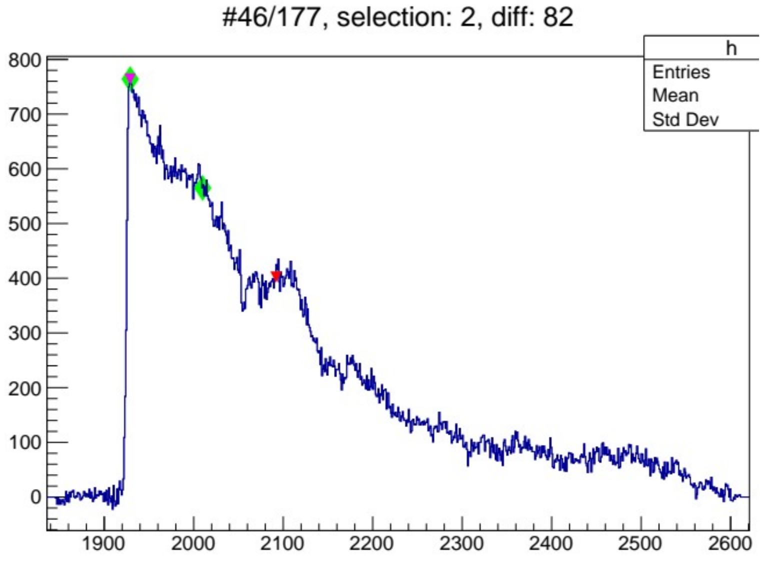
- Goal is to see how well we can tag Michel electrons using only the PDS
  - Gives complementary result to TPC
  - Calibration of PDS
  - Contributes to muon charge ID

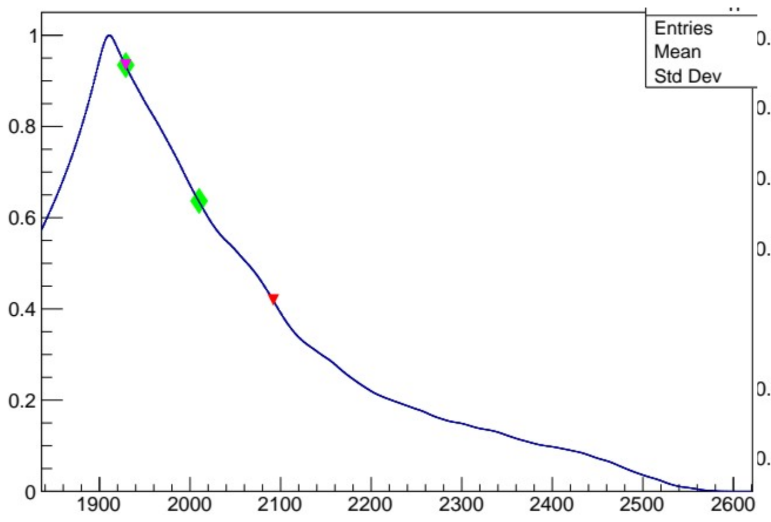
- Other work:
  - Kyle Spurgeon did the initial work on this project
  - Aleena Rafique has been doing Michel tagging using primarily the TPC

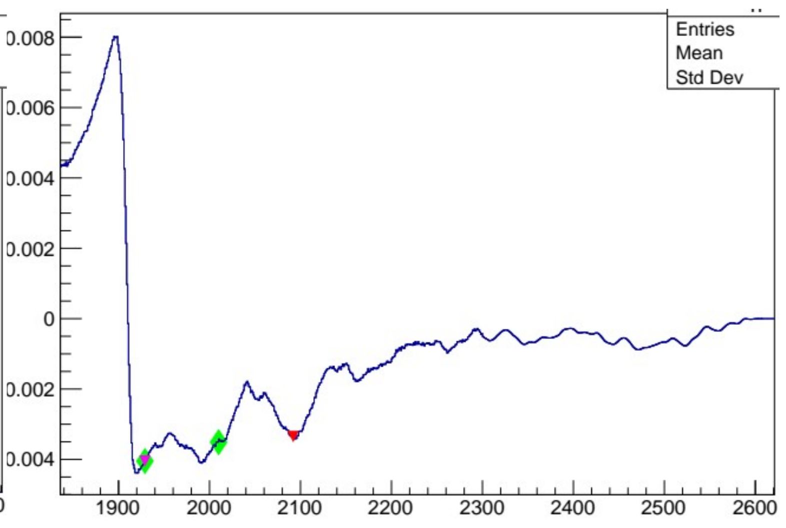
- My general approach is to assemble a waveform from the PDS, filter it, and the identify relevant features

Reminder: My Algorithm

- Convolve the waveform with a template signal (300 ticks)
- Take the first derivative
- Find the minima and maxima of the processed waveform
- Take the biggest drop, and designate it the reconstructed muon
- Find the second-largest drop after the muon and call it the reconstructed Michel



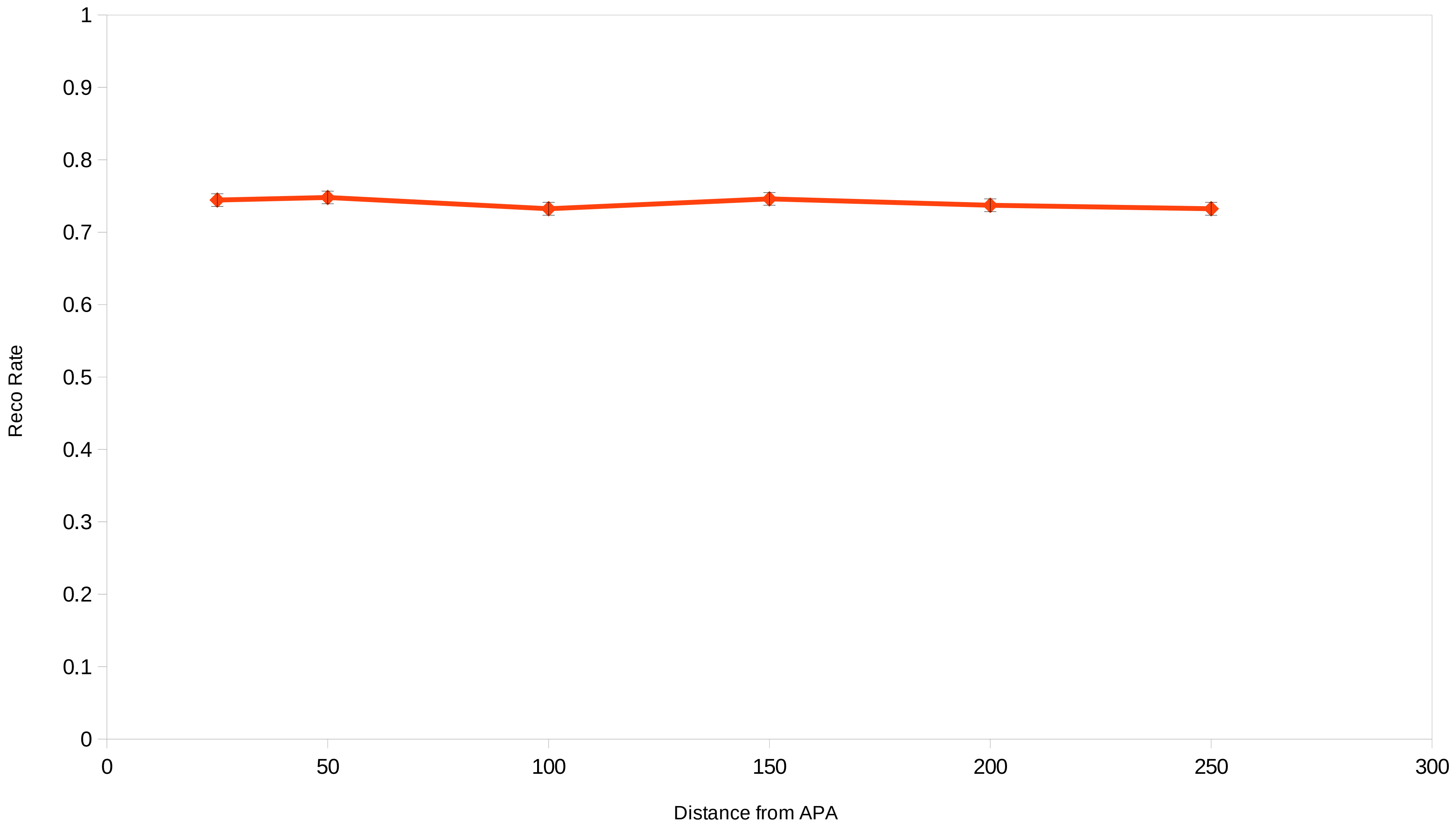




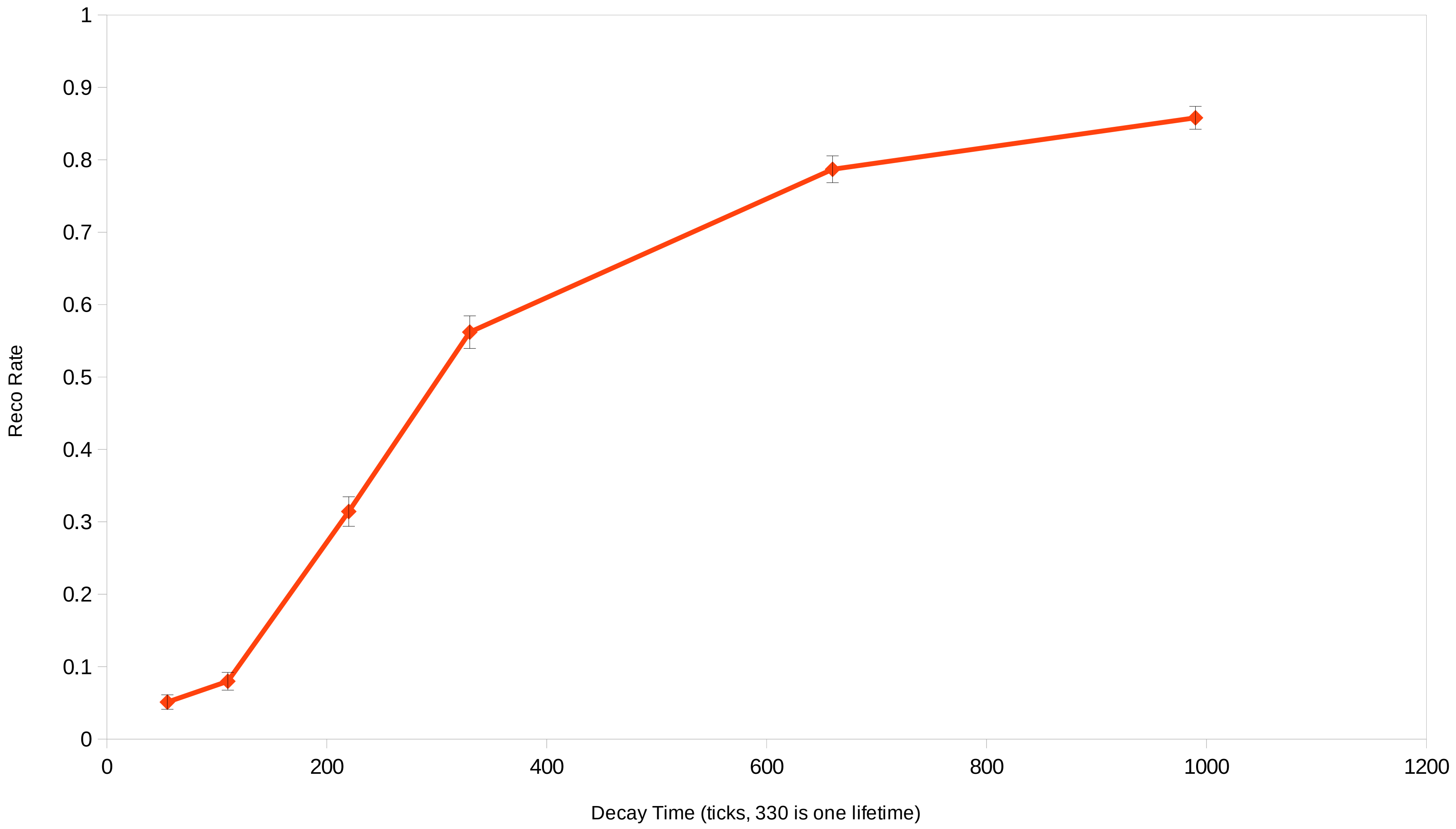
Toy Monte Carlo

- I have been using a module developed by Peter Madigan (Berkeley) to generate signals close to those produced by actual muons and Michels, but with greater control than the full simulation can offer
  - I can also generate large samples in relatively small times, greatly improving my statistics
- This control allows me to measure the performance of my algorithm in various circumstances, namely:
  - Stopping position
  - Decay time
  - Muon energy

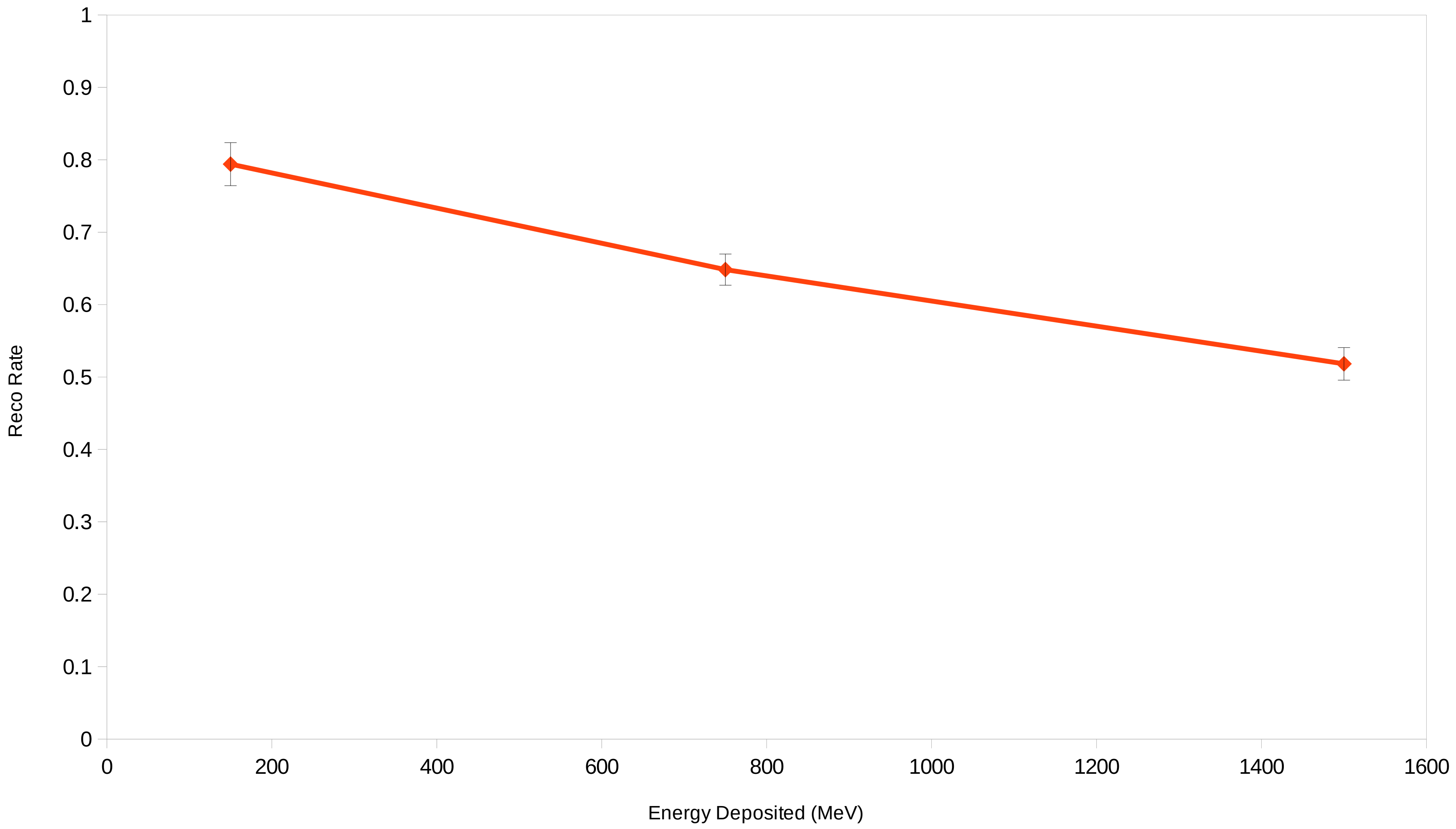
Stopping Position



Decay Time

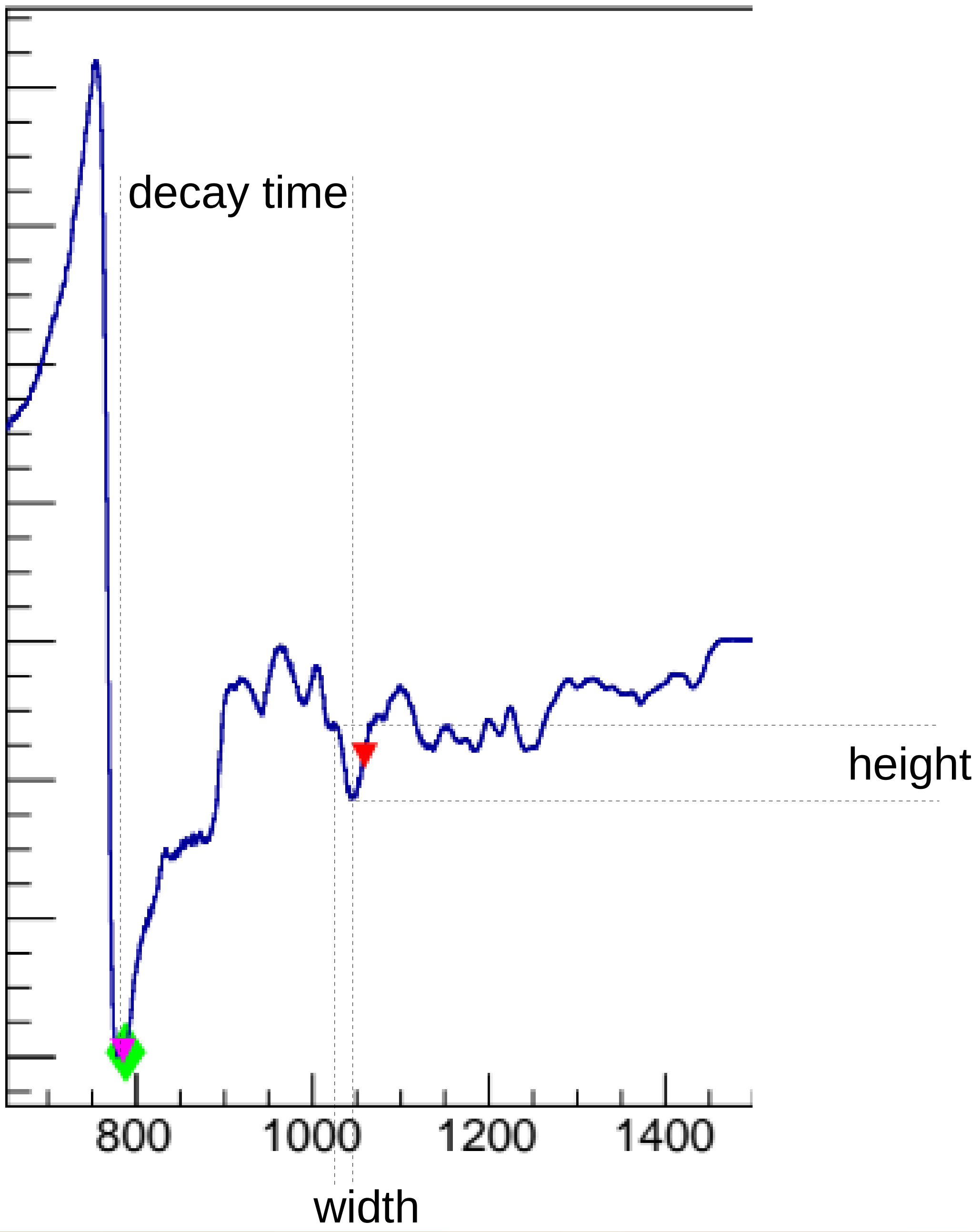

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Reco Rate
0
200
400
600
800
1000
1200
Decay Time (ticks, 330 is one lifetime)

Muon Energy Deposited



Quality Cuts

- Goal is to perform a cut on some metric to categorize events as having a Michel or not: if the dip corresponding to the reconstructed Michel has a metric greater than some threshold, the event is considered as having produced a Michel, and otherwise as not.
- I experimented with many metrics involving height (size of the drop measured in the processed waveform), width (post-transform ticks the drop takes), and decay time (reconstructed)



Quality Cuts

- While peak-finding with some metrics performed slightly better than height alone, cutting on height alone has so far produced the best results
- Using muon information in the metric makes everything worse
- Attempts to peakfind on one metric and cut on another are ongoing, but so far have yielded very little improvement

Scoring Quality

- For various metrics I measured two scores:
  - Purity = TP/(TP+FP), the proportion of events reconstructed as having a Michel which actually do
  - Efficiency = TP/(TP+FN), the proportion of events which actually have a Michel which were reconstructed properly

- I have been measuring the performance of a cutting method using the recall at a fixed purity of either 90% or 95%
  - This is far from the only use case, but I need to choose a consistent method of evaluation
  - Fixed purity is a simple evaluation applicable in many cases that does not require fine-tuning

Scoring Quality

- At 1m from the APA, proper decay spectrum, 1.5GeV deposited energy, with height alone as the metric:
  - At 90% precision: 79% recall
  - At 95% precision: 66% recall

- In general:

Muon energy $\uparrow$ Performance $\downarrow$

Decay time $\uparrow$ Performance $\uparrow$

Distance from APA $\uparrow$ Performance $\downarrow$

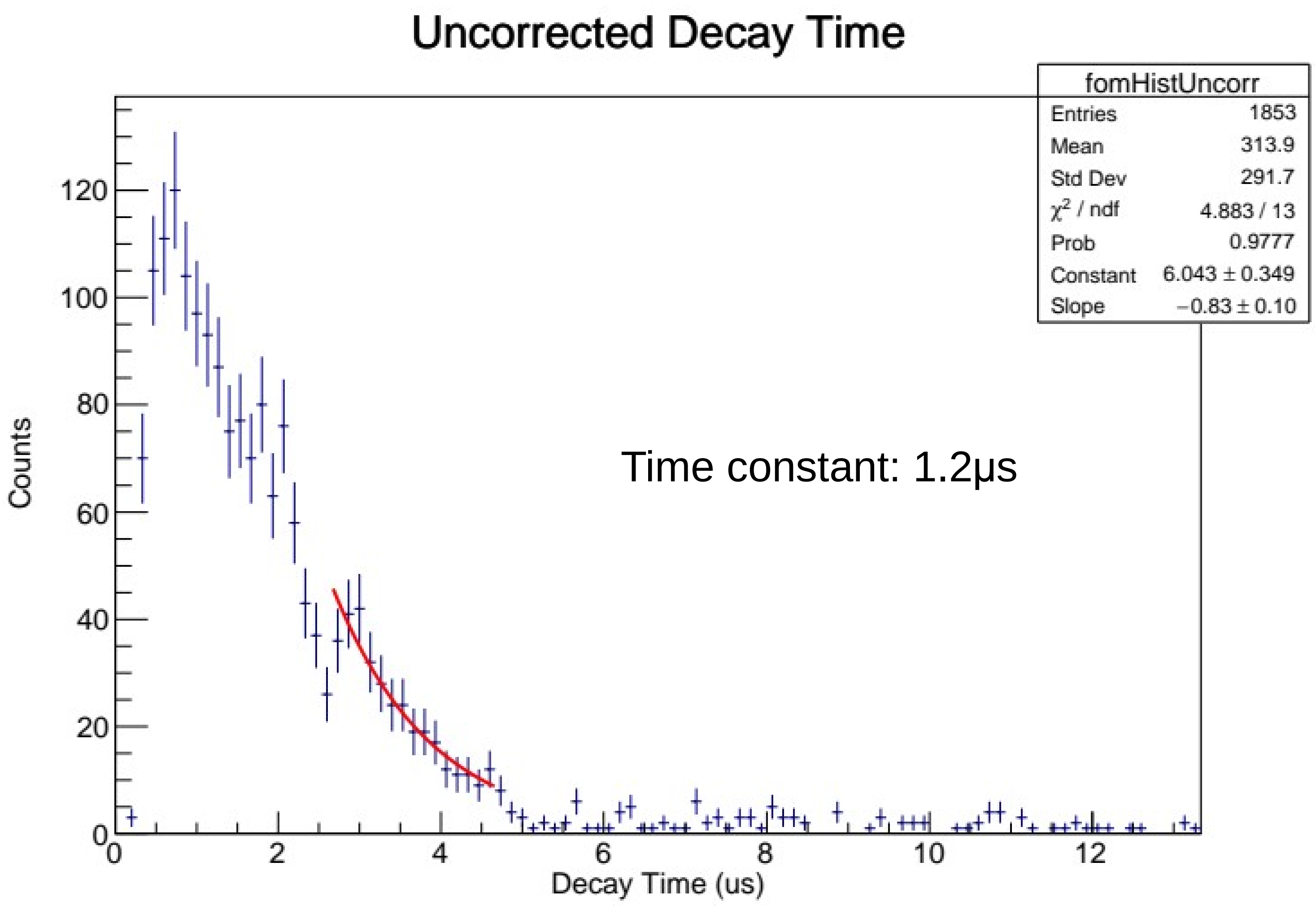
Bringing it Back to Data

- I re-ran on the set of ACTUAL PROTODUNE DATA from last time- essentially, a collection of non-coincident CRT triggers across a few good runs assembled by Kyle- slightly over 2600 events
- Processed with the latest version of my algorithm, using the 90% purity cut as derived from Monte Carlo
  - Probably more performant in data due to the data's distribution of muon energies being more favorable to reconstruction
- Fit on the time range where the MC achieves highest purity (and the data has enough events)
- Relevant time scales:

Source	τ
μ^+	2.2μs
μ^-	0.57μs*
$\mu^{50/50}$	1.9μs
Late light	1.5μs

*M. Sorel: Expected performance of an ideal liquid argon neutrino detector with enhanced sensitivity to scintillation light https://arxiv.org/pdf/1405.0848.pdf

Data Results

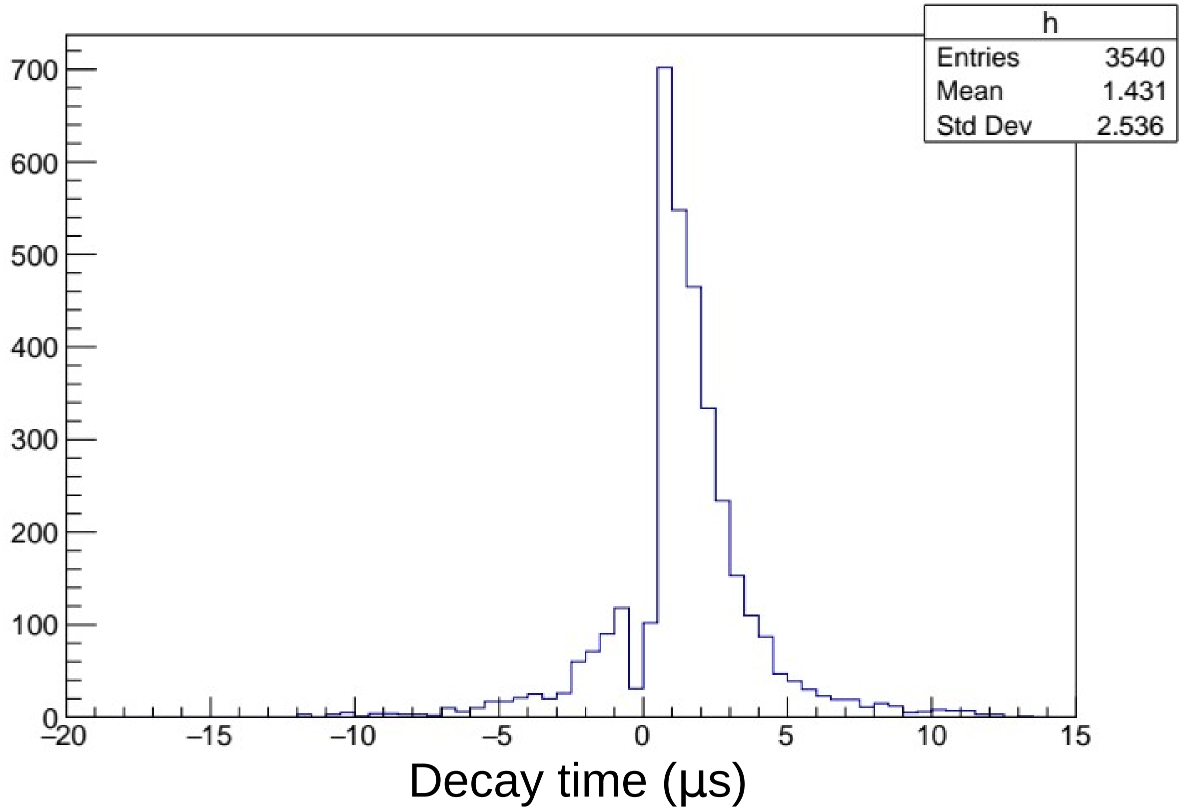


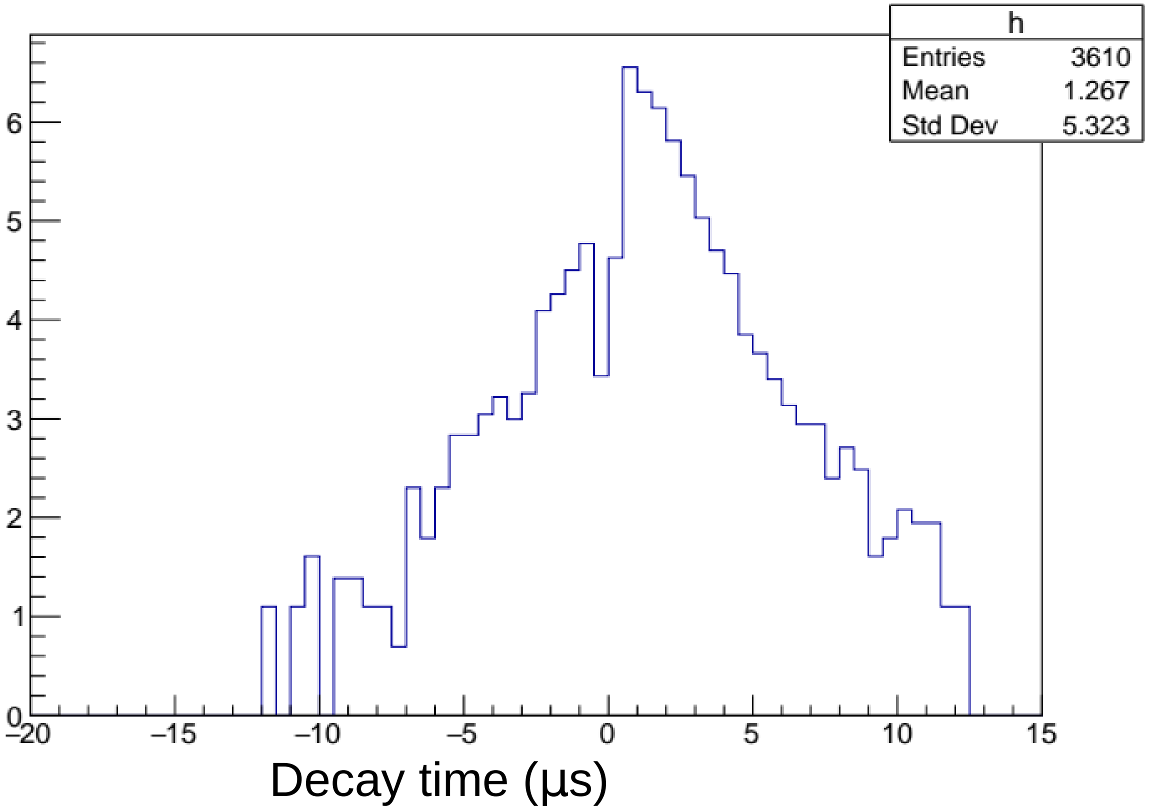
Conclusion and Next Steps

- Overall, a decent reconstruction rate in the most relevant regimes
- Cuts can yield either a high purity with good recall or a balance between the two
- Analysis on ProtoDUNE is promising, but needs efficiency corrections
- Next steps:
  - Apply an efficiency correction
  - Do a short version of these studies for some of my past filtering methods
  - Determine what counts as “good enough” in precision vs recall to be useful to physics goals and supporting the TPC

Backups

New Results

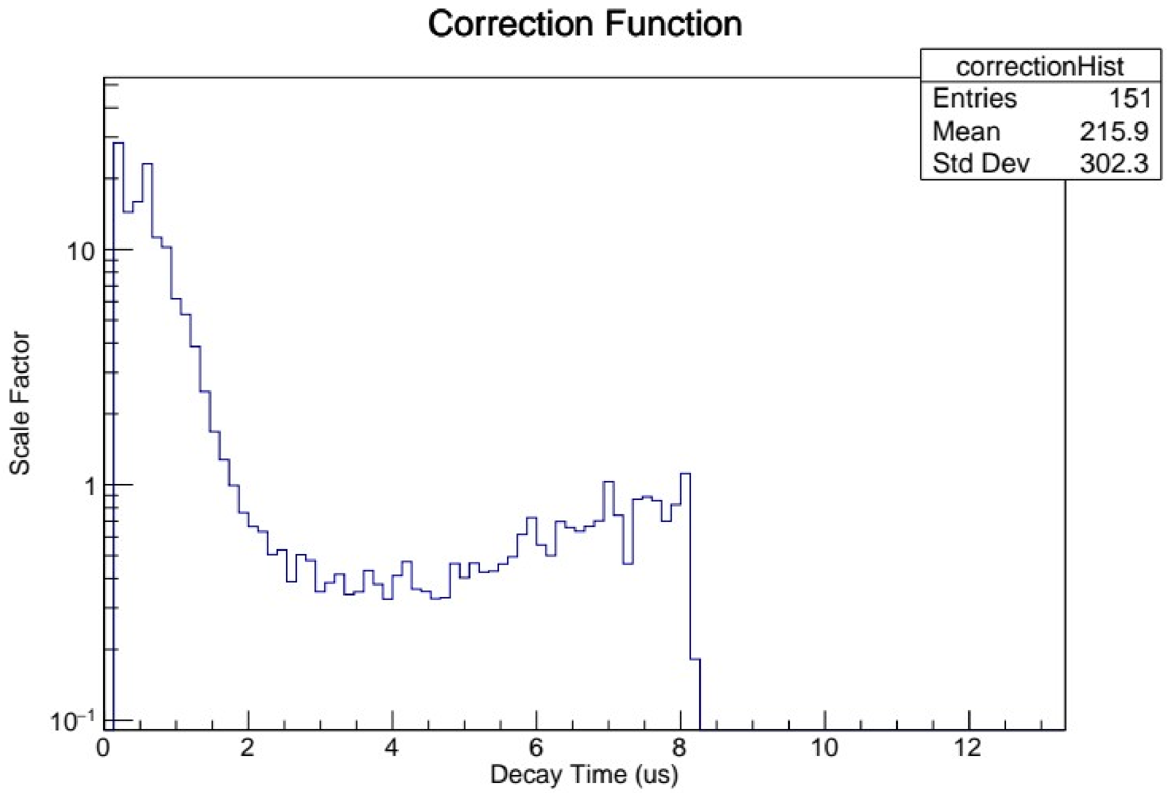


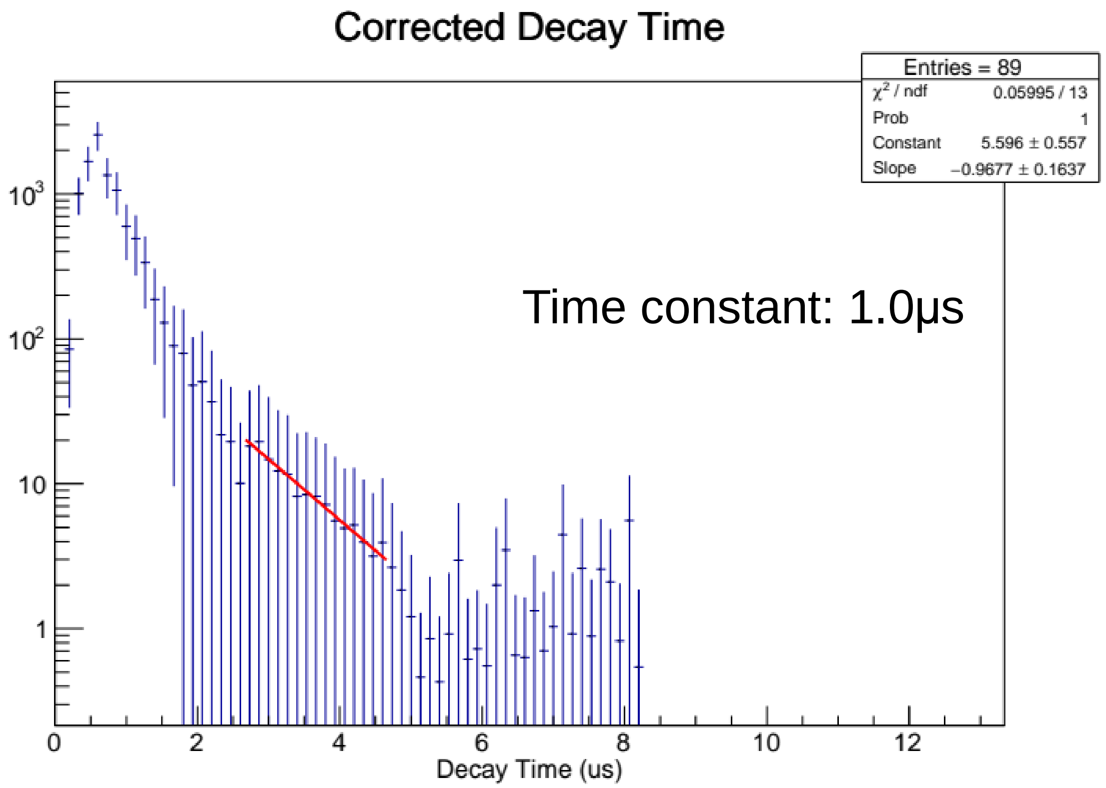


- This uses an "old" method- rectangular filter followed by differentiation and SG degree 6 fit
- This is a run over DATA, selected using the TPC for events which probably have michels
- Unlike in Kyle's plots, my mis-identified events appear to be very correlated, causing significant shape distortion.
- A re-run with the updated algorithm is pending

Efficiency Correction

- Also attempted an efficiency correction
  - I took the ratio of the true time histogram of all MC events to the reconstructed time histogram, and then multiplied this into the data hist





Efficiency Correction Caveat

- But, the efficiency correction is performed assuming a lifetime of 2.2μs.
  - Because the 1.5μs timescale of the late light is constant, the correction function cannot be easily rescaled
  - This prohibits any easy sort of convergence rescaling

Log Scale Uncorrected